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ABSTRACT

This document outlines and discusses 67 minimum standards for good science teaching in elementary, middle/junior high, and senior high schools. The standards are presented in three sections. The first section (resources for learning) considers science spaces/places (laboratories, classrooms, individual study), science learning materials, science programs, and science teachers. The second section (conditions of instruction) focuses on teaching assignments, working space, services, and budgets. The third section (professional growth) addresses standards related to the professional library, continuous learning, and professional recognition and incentive. Each standard and related discussion is designated by one or more school level codes (ES for elementary school; MS for middle/junior high school; HS for high school) and a number (from 1 to 67). These numbers are a marking system, not a ranking of importance. In addition, the numbers appear in duplicate or triplicate if items have been tailored to a specific school level. Selected standards include conducting an annual verified safety check of laboratories and providing: (1) a student-teacher conference area; (2) 150 minutes per week of science learning activities at the elementary level; and (3) full audiovisual capability, facilities for conducting scientific demonstrations, and access to a computer. (JN)

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Conditions for Good Science Teaching

Edited by Victor M. Showalter

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Using This Book

There are 67 numbered items addressed in this book. The numbers are a marking system, not a ranking of importance. The numbers appear in duplicate or triplicate if the items have been tailored to a school level.

The three-cornered marker designates the school level to which each item or discussion is directed. ES refers to elementary school. MS refers to middle/junior high school. HS refers to high school.

Introduction

How does a science teacher design a science program? How does a science teacher make an existing program better? What facilities are needed to create a safe and efficient laboratory?

These are some of the questions considered by the teachers who wrote this book. Our answers are drawn from decades of science teaching and science teaching research. We hope that this volume provides a foundation on which to build an exciting, challenging, and safe science program for students and teachers.

This volume is a revision and expansion of the 1970 book *Conditions for Good Science Teaching in Secondary Schools*. The earlier volume was the result of the work of the Commission on Professional Standards and Practices which was established by NSTA. That commission was instructed to carefully study all aspects of effective science teaching, to consult widely, and then to prepare a statement that could serve as a guide to science teachers and school adminstrators wishing to provide their students with a good science education.

To produce this edition, the 1970 volume was critically reviewed by the 1981-1982 Ad Hoc Committee on Standards and Conditions for Science Teaching. Eight people were then selected from working subgroups of NSTA, and a guide for review and a copy of the original document were sent to each person. The guide asked specific questions about format, organization, potential new items, and current validity of each item in the original document.

The reviewers agreed that science teaching was essential at all grade levels, so it was necessary to define conditions of good science teaching at all grade levels. The expansion of the text to include elementary and middle/junior high conditions for good science teaching was addressed by each reviewer.

Responses to the critical review were tabulated and sent to members of the Ad Hoc Committee on Standards and Conditions for Science Teaching. Each member prepared a draft revision of a specific section of the original document, based on the critical reviews. The combined drafts were then circulated among the committee and their responses were sent to the chairman, who collated them, resolved differences, and edited the material into a consistent format. The complete draft was discussed in open session at the 1982 NSTA National Convention and the final draft prepared, incorporating consensus reactions from the session. The final draft was approved by the Board of Directors in late summer, 1982.

Our committee recognized that it was not possible to specify every detail of science teaching. Far too many variables exist. For example, research can show that without adequate laboratory facilities and materials most students cannot learn biology in any meaningful way. Conversely, we cannot be sure that meaningful learning will take place with such facilities and materials.

In this book, we present the conditions that we know will help administrators, teachers, and students evaluate their present science program, and plan future programs.

Victor M. Showalter
Chairman, Ad Hoc Committee
on Standards and Conditions
for Science Teaching,
1981–1982

The National Science Teachers Association develops publications designed to help science teachers assess their science programs. One such publication, *Conditions for Good Science Teaching in Secondary Schools*, was originally developed a number of years ago to assist secondary school science teachers. It has recently been updated to include requirements for good science teaching in all grade levels.

The conditions included are reasonable; they represent

the accumulated knowledge and expertise of some of the best science teachers in the nation. Many of the conditions seem ideal, but they are the minimum standards for science classrooms. These standards are necessary to encourage future scientists and scientifically literate citizens. As science educators, we are called upon to offer suggestions for the improvement of programs in our classrooms. This publication can provide the support and information needed to respond to questions about improving science programs in your schools.

Robert B. Sigda
NSTA President 1983-1984

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Resources for Learning

From the standpoint of a student, it is reasonable to look upon schools as institutions that provide resources for learning. These resources include all things and procedures that aid, facilitate, or provoke learning. Learning resources include people and programs, not just buildings and books. A school that has well equipped science laboratories but poorly trained science teachers—or ill-equipped laboratories and excellent teachers—cannot claim to have adequate science learning resources. Nor can a school be satisfactory if it lacks the science experiences to serve all students.

Thus, in any school, resources for learning should include

- Suitable spaces/places for learning science.
- Appropriate and sufficient science learning materials.
- A modern and comprehensive program of science instruction.
- Competent and enthusiastic science teachers.

Science Spaces/Places

Certainly there is some element of truth in the idea that learning can take place anytime, and under any circumstances. But the larger truth is that systematic, effective learning by large numbers of students at a given time requires the provision of learning spaces specifically designed for that purpose. These learning spaces and their furnishings must take into account: (a) the great diversity of students who will use them, (b) the nature of present day science and technology, (c) current trends and approaches to science teaching, (d) the safety of students, and (e) flexibility, for adaptation to future uses. The consequence will be well-furnished, safe, interesting science rooms that include spaces for laboratory work, for group instruction, and for individual use. These rooms will be an open invitation to learning and teaching.

Laboratories

It is generally agreed that science is a process and an activity as much as it is an organized body of knowledge; science cannot therefore be learned in any deep and meaningful way by reading and discussion alone. Science education should promote learning activity, creativity, and involvement in acquiring data systematically (i.e. laboratory work). The recommendations that follow are offered as an aid to designing or improving science laboratory space in schools.

ES **1 Elementary science teaching involves processes, concepts, and topics that are often best taught in connection with other subjects such as reading and mathematics. This can best be achieved when children do laboratory work in their regular classrooms. Classrooms should be designed and equipped to accomodate such work.**

It is usually desirable to establish a separate room as a science resource area, perhaps adjacent to a media center. This, however, would be supplementary to the basic program.

MS **1 All science laboratory/classrooms should be multidisciplinary.**

- Science laboratory classrooms should be reserved for science classes.
- Some unscheduled laboratory time should be available each day.
- Special attention should be given to the maintenance of living organisms.

HS **1 Laboratories should be designed and equipped to accommodate more than one area of science in order to explore all the experimental solutions of a problem.**

In addition there must be sufficient flexibility to meet the variations in the yearly demand for science courses. This seems a challenge to those responsible for scheduling, but the educational benefits of such flexibility outweigh the disadvantages.

One danger in this approach is to carry this arrangement to an extreme that makes the entire science program logistically unmanageable. There are three imperatives implicit in this recommendation:

- Science laboratories/classrooms should be reserved for science classes.
- Some unscheduled laboratory time should be available each day.
- Special attention should be given to the maintenance of living organisms.

2 Because elementary science instruction usually occurs within each classroom, this room should be designed and equipped to serve as the laboratory setting.

2 All students enrolled in science courses should have daily or frequent access to science laboratories. This applies equally to students whose goal is to be a science specialist as well as to students whose goal is general scientific literacy. Restricting enrollments to accommodate existing laboratory facilities is not acceptable practice.

Laboratory experiences have been shown to increase positive attitudes toward science. There is also evidence to show that the laboratory is an effective setting to develop manipulative skills, processes of science, interest, and values. Based on this research and other psychological studies on the use of concrete manipulative materials, one risks much by minimizing laboratory work in the science program.

- At least 40% and no more than 80% of total instructional time should occur in a laboratory setting.
- Sufficient laboratory rooms should be available to accomodate all students for a full year of science each year.

3 In the elementary school, the physical organization of the classroom should be flexible enough to allow sufficient space for setting up, conducting, and storing experiments or projects.

- There should be a minimum of 4.8 square meters of space per student.
- No more than 24 students should be assigned to one teacher for laboratory experience at any one time.

3 Each laboratory should be large enough to allow full student participation in setting up, conducting, and storing experiments.

- In combination classroom/laboratories, approximately 2/3 of the space should be set aside for the laboratory and 1/3 should be used for discussion, lecture, and other activities.
- There should be a minimum of 5.5 square meters of space per student in a classroom/laboratory.
- There should be a minimum of 4 square meters per student if the space is strictly for a laboratory.
- No more than 24 students should be assigned to a laboratory and a teacher at one time unless the school has been built following an open area concept.

4 Classroom and laboratory ceilings should be high to provide enough room volume to dissipate odors, heat, and fumes generated by experiments. A fume hood should be used when necessary.

- There should be 3 meters between floor and ceiling.

- Ceilings must be of non-asbestos, flame retardant material.
- Acoustical ceilings are desirable.

5 A laboratory should provide a setting for student experimentation and this environment should be provided within each classroom. Each classroom should include work space, storage facilities, and appropriate science equipment and supplies.

- Level student tables or other work surfaces should be provided.
- Storage space for individual student projects should be provided.
- Lockable metal storage cabinets for selected science materials should be available either in the classroom or in a convenient central location.
- Special equipment should be kept simple and should include such items as a microscope, simple two-pan balances, thermometers, plastic beakers, etc.

5 Each laboratory or laboratory/classroom should be appropriately furnished for the science classes that will use it, including work space, storage facilities, and frequently used equipment and supplies.

- There should be at least 1 square meter per student of work space that is smooth, unobstructed, and level.
- A secure preparation room should adjoin or nearly adjoin the laboratory.
- There should be a demonstration table approximately 91 centimeters high.
- All counter tops should be acid proof and heat resistant.
- Considerable space near windows should be adapted for plants.
- Cabinetry should accommodate the equipment and supplies needed for science teaching. All storage areas and cabinets should be lockable.
- Facilities should allow for proper organization of materials.
- Special equipment should include a temperature control chamber, balance, microscopes, water deionizer, stream table, electronic meters, etc.

5 Each laboratory or laboratory/classroom should be appropriately furnished with work space, storage facilities, and frequently used equipment and supplies for the science classes that will use it.

- There should be at least 1 square meter per student of work space that is smooth, unobstructed, and level.
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- There should be a demonstration table approximately 91 centimeters high.
- All counter tops should be acid proof and heat resistant.
- Considerable space near windows should be adapted for plants.
- Cabinetry should accomodate the equipment and supplies needed for science teaching. All storage areas and cabinets should be lockable.
- Facilities should allow for proper organization of materials.
- Special equipment should include autoclave, incubator, refrigerator, microprojector, centrifuge, spectrophotometer, analytic balance, electronic meters, water deionizer, stream table, etc.

6 Each classroom should contain a sufficient number of conveniently located electrical outlets, at least one large sink at a height appropriate for the students, and low pressure water.

- All sinks should be at least 45 centimeters by 61 centimeters, have hot and cold water, and be low enough for student use.
- All electrical outlets should be covered and grounded.

6 Every laboratory should have a sufficient number of conveniently located electric, gas, and water sources.

- The demonstration table should have electricity, gas, hot and cold water, and a large sink.
- All electrical outlets should be covered and grounded.
- One electrical outlet should be available for every two students.
- Water faucet spigots should be high and should yield water at low pressure with an aerator.

7 Appropriate waste disposal facilities and procedures must be provided for all laboratories.

- Maintain no more than a 2-year supply of all chemicals.
- A yearly inventory of materials is essential.
- An approved local handbook on waste disposal should be readily available to all teachers at all times.
- Separate containers should be available for broken glass.
- A periodic check with local authorities should be made to determine current procedures for disposal of substances that are flammable, insoluble, or toxic.

8 Each laboratory/classroom should provide adequate, energy efficient lighting and temperature control for the work to be done.

- One hundred foot-candles of diffused light at desk level should be adequate for most situations, although detailed close work may require a 30% increase.
- Solar energy should be used directly when possible for light, heat, and maintenance of growing plants.
- Daylight bulbs may be more appropriate than cool white bulbs.
- Workspaces along walls should be equipped with counter lights.
- Systems to control light and temperature levels should be provided.

9 Internal air circulation and external exhaust systems should be part of the laboratory/classroom.

- Exhaust fans should be capable of moving 28.3 cubic meters of air per minute.
- Windows that open are necessary in the absence of mechanical exhaust systems.
- Fume hoods should be located in all laboratories that generate toxic or noxious vapors. A velocity of 9.3 linear meters per minute is a minimum and all ductwork in the building should be under negative pressure.

10 A fully operable fire extinguisher should be available within each laboratory/classroom.

Teachers should be skilled in using the extinguisher.

10 Fully operable fire extinguishers should be located in each laboratory where they are quickly and easily accessible. Fire extinguishers should be appropriate to the type of fires that might occur in the laboratory.

- All chemistry laboratories should contain a dry chemical powder (pressurized bicarbonate) and/or a carbon dioxide fire extinguisher, up to a 4.5 kilogram charge.
- A Halon 1301 fire extinguisher may be needed in

certain electronics areas.

- Teachers should know how to operate the available fire extinguishers.
- Storage of chemicals should be by category and not by alphabetical order.

11 All students should be provided with safety goggles.

- Goggles should offer splash and impact protection from the front and sides.
- Storage and disinfection of goggles should be arranged.
- Teachers should be knowledgeable about the use of goggles.

11 Laboratory/classrooms should contain eye-wash fountains and safety goggles for all students.

- Chemistry laboratories and all preparation rooms should contain an emergency safety shower and drainage for the shower. A hand-held eye wash spray with a 1.5 meter hose is most adaptable to unusual situations including head and body splashes.
- Goggles should offer splash and impact protection from the front and side.
- Storage and disinfection of goggles should be arranged.
- Teachers should be familiar with the use of the safety systems.

12 Every science laboratory/classroom should have two unobstructed exits.

- These should open directly into a main hallway or to the outside of the building.
- Ideally, doors to these exits should not be locked against inside to outside passage.

13 There should be an annual verified safety check of each laboratory.

This can be conducted during the summer by the local fire marshal and the school's maintenance staff following a check list provided by the science chairman or lead science teacher. At the beginning of the school year, each science teacher should receive written notification of the results.

Classrooms

In the traditional mode of instruction, students are brought together in groups of moderate size for purposes of discussion, demonstrations, watching films, and the like. While other approaches to science teaching put more emphasis on individual student activity, they too usually require space for group work. The following recommendations apply to such spaces, whether they are provided as part of laboratory/classrooms or as separate rooms.

14 For effective learning, no more than 24 students should be assigned to a space intended for group discussion and activity (as distinct from large-group lecture).

This recommendation should not be taken to discourage experimentation with innovative ways of grouping students for instruction, provided they are based on educationally defensible premises. It does oppose taking the chance of undermining effective group teaching for reasons of scheduling convenience or to lower costs.

15 A science classroom should have full audiovisual capability, facilities for conducting scientific demonstrations, and access to a computer.

A science classroom should be equipped with a demonstration table with a sink; electrical, gas, and water services; outlets for audiovisual equipment; screens for regular and overhead projection; provision for darkening; ample blackboard space and bulletin board display space.

Individual Study

As a consequence of continued concern for individualized instruction and of increasing emphasis on the use of computers and other media, there is a trend toward more and more independent learning activities as an integral part of science programs. While there will be continued use of group learning and teaching procedures, it is imperative that every school make provisions for accomodating individual learning activities in order to assure excellence in science learning. The following recommendations apply to any school, regardless of the mix it may currently have of group and individual learning activities.

16 Specialized facilities are needed.

There should be access to a shop or a tool cart for construction projects. A natural outdoor area should be maintained and easily accessible for science learning activities.

These should include at least a greenhouse or plant growth facilities, an animal room, a darkroom, and access to a shop. Outdoor facilities on the school site should be preserved or restored to natural conditions and used for science teaching.

17 Individual project areas are needed for students working on special experiments.

Many experiments require several days to complete and undisturbed space should be available for them.

Ample storage for projects in progress is as necessary as adequate working space.

18 Ample library space should be available.

Ideally this will be a spacious, easily accessible school library or learning center.

This should be concentrated in the school's general library but may include a small working library within the laboratory or classroom. The library should be easily accessible at a variety of times and large enough to accommodate a sizable number of students.

19 A teacher-student conference area is needed.

These conferences often require isolation from the students' peers and may be conducted when the classroom is unoccupied. However, an alternative, pleasant, non-threatening site should be provided by the school for use at other times.

Such conferences will ordinarily occur in the teacher's office. If, contrary to these recommendations, such space is not available then the school should provide a special conference room.

Science Learning Materials

If we consider the great variation in student interests, purposes, abilities, learning styles, and background, and then contemplate the complexity of science itself, there appears an obvious need for a wide assortment of science learning materials. The following recommenda-

tions are intended to offer guidance in selecting these materials.

20 Individual science textbooks, laboratory manuals, and/or study guides should be made available without cost to every student.

All students need a guide to lead them through the conceptual and process-based aspects of science units. Such a guide, whether it be one or more textbooks or other printed materials, should be made available to each student at all times through a course.

21 The science textbooks used by students at any time should be no more than five years past the date of the last major revision.

Science is dynamic, this is dramatically true of the applications of science. One consequence of this is that textbooks, which are somewhat dated even before they appear in the schools, become obsolete more rapidly than textbooks in other fields. All science materials need to be up-to-date in content, organization, topical interest, and spirit.

22 At every level in the science program there should be a variety of printed materials to supplement a basic textbook, laboratory manual, or study guide.

This material should be in each classroom and could include trade books, newspaper clippings, word puzzles, coloring books, etc. A library cart can be stocked with appropriate materials to complement each unit as it is taught.

No guide, no matter how good, serves all students equally well. To back up the basic materials, the science department should stock in the classrooms and laboratories and integrate with the courses such printed materials as programmed instruction booklets; a selection of textbooks, magazines, articles, and leaflets. Some material should deal with the connections among science, technology, and the rest of society.

23 The school or system library or media center should contain a variety of trade books, pamphlets, and bulletin board display material on science, technology, and social aspects of science.

Encyclopedias, biographies, science fiction, and nonfiction materials should be included. Some periodicals can be included. Guidance in selecting these materials can be found in professional journals. (These materials can be the source of selections for the library cart described in recommendation #22.)

23 The school library or media center should contain an adequate selection of books, periodicals, and pamphlets on science, the applications of science, and the history, philosophy, and sociology of science.

Encyclopedias of science, science dictionaries, field books, handbooks, nonfiction, biographies, novels, a large selection of popular science magazines, and files of pamphlets and documents from government agencies, industry, and scientific societies should be included. The reading level, mathematical sophistication, and level of abstraction should vary to include works ranging from junior high school level to college level. Guidance in selecting materials should come from the science teachers and the science department head.

24 An adequate supply of modern science supplies and equipment should be available for individual and small group activities and experiments.

Laboratory learning requires equipment and supplies in sufficient quantity for conducting experiments. The kinds and quantity of equipment needed cannot be specified without knowledge of the particular units taught and of the relative emphasis placed upon group instruction and on individual experimentation. A supply system for delivery and replacement of consumables should be established. Because young students especially benefit from hands-on learning, elementary classrooms should be well supplied with appropriate, inexpensive, and easily obtained materials.

Laboratory learning requires materials, equipment, and supplies in sufficient quantity for conducting experiments. The kind and quantity of equipment needed cannot be specified without knowledge of the particular courses taught and of the relative emphasis placed upon group instruction and on individual experimentation. A supply system for delivery and replacement of consumables should be established.

25 A diverse supply of audiovisual learning materials needs to be readily available for each science unit.

Slides, overhead transparencies, videocassettes, computer programs, and films, etc. are best regarded as permanent equipment and kept in the rooms where they will be used. An efficient, schoolwide central supply system could also store this equipment.

Those materials used frequently, such as film loops, slides, videocassettes, overhead transparencies, and computer programs, should be regarded as permanent equipment and be located in the rooms where they will be used, in an adjacent storage area, or in a media center. They should be readily available to teachers and students. Other materials, such as 16 mm sound films, that are used a few times a year and are relatively more expensive, can be obtained by loan. An adequate budget for maintaining, replacing, and adding to these materials should be provided.

26 Individual classrooms should have permanent use of certain items of audiovisual equipment, or this equipment should be easily accessible.

This equipment should include microcomputer(s), overhead projector, and videocassette player.

26 Certain items of audiovisual equipment should be provided as the permanent equipment of individual courses and/or classrooms.

Many science teachers use audiovisual equipment frequently. Items such as overhead projectors, microcomputers, videocassette players, and film loop projectors need to be available without excessive planning and formal ordering.

Science Programs

In any school district an organized, sequential K-12 science program will offer the best opportunity for all students to achieve desirable levels of scientific literacy. It is generally agreed that no one science program will best serve all schools and/or districts. It is also agreed that good science programs do not happen by chance but result from concentrated and continuing development. The following recommendations are intended to guide this development.

27 The science program should provide appropriate science experiences for each student at every grade level.

Special efforts should be made within each classroom to assure individual student success. Consequently, the cognitive and manipulative demands of learning science should match the developmental levels of individual students.

27 The science program should provide an appropriate science course for every student every year.

It is generally agreed that not all students must take exactly the same courses, but each should achieve a satisfactory level of scientific literacy. Courses should provide background for and inspire interest in high school science.

27 The science program should provide the opportunity for every student to study science every year.

Whether a school requires one or two or more years of science for graduation, there should be a science option for every student every year. The group of courses available may be traditional or non-traditional, but should be sufficiently diverse in level and approach to give every student a choice in which he or she can be successful, given the student's interests, abilities, and developmental level.

28 The science program should provide an opportunity for all students to explore the spectrum of human scientific endeavor and its relationship to the whole of society.

The processes of science should be emphasized as a way of learning and accorded at least as much priority as the cognitive aspects of science. Science-related career aspirations should begin to develop as a consequence of studying science.

Science and technology will provide careers for many students and will influence the lives of all students. The processes or methods of exploring and understanding science should not be omitted in favor of the primarily cognitive aspects of science.

Science should be seen as one significant way of knowing the universe.

29 The science program should provide opportunities for science-oriented students with high ability and/or high interest level to be involved in activities that go beyond the regular units.

These opportunities could include extended field trips, working with older students, acting as laboratory assistants to teacher(s), teaching younger students, conducting independent projects, etc.

29 These should include at least the opportunity to work on an independent research project for which adequate space, materials and teacher help are made available.

These opportunities could also include special research seminars and extended field trips.

30 There should be at least 150 minutes per week of science learning activities available to every student.

The effects of science education extend beyond the immediate facts learned. Science learning enhances the basic skills of reading, writing, and mathematics, and is fundamental to educational development.

30 Every student enrolled in a science course should have at least 225 minutes per week of science instruction in schools with block scheduling, 270 minutes per week of science instruction in schools with modular scheduling.

Field studies and laboratory work require time in addition to the usual classroom time allotted to other school subjects.

30 Every student enrolled in a science course should have at least 275 minutes per week of science instruction in schools with block scheduling, 315 minutes per week of science instruction in schools with modular scheduling.

31 All science units should include a significant amount of student laboratory work. Studies have shown that younger students especially benefit from hands-on activity. This does *not* mean watching a teacher or peer perform a demonstration (although this may be useful occassionally). Manipulative skills and interest in science are developed along with cognitive knowledge.

- Laboratory work is not an end in itself and must be followed by some "intellectualization" of the results.
- Questions and answers based on observations are more important than "right" answers.
- All students, regardless of demonstrated ability, should be involved in laboratory work.

31 All science courses should include a significant amount of student laboratory work. Experimentation is the heart of real science and can be defined as the systematic gathering and interpreting of observations to answer a question or to test an hypothesis. Sometimes this is extended to include any hands-on activity.

Experimentation is needed to convey the reality of science and the processes of science.

- Most experimentation should be based on real problems and should be open-ended.
- All experimentation should be relevant to other portions of the course.
- All students, regardless of ability levels, should be involved in experimentation.
- Experimentation can involve data gathering from any part of the real world and need not be restricted to the laboratory/classroom.
- The manipulative aspects of experimentation are not sufficient in themselves and must be followed by analysis and interpretation.

32 A variety of learning-teaching activities should be incorporated into each science course.

Experience shows that the best method of teaching science is a mix of methods. Any one method (even laboratory) used to the exclusion of all others is not likely to be effective.

Any group of individuals will have a variety of preferred learning styles which must be accommodated.

33 The science program should be continually reviewed. A general review should be done annually and a detailed critical study should be done at least every five years. Leadership for this effort should come from the science chair or lead teacher.

Each science teacher should participate in a systematic plan to review the school science program in terms of

- overall program objectives.
- progress toward objectives at each grade level.
- needed modifications within the program at each grade level.
- articulation among grade levels and with the middle school program.
- how well the teaching methods fit student learning styles.
- equipment and facility needs.

33 The science program should be continually reviewed and developed. The review process should involve the entire science teaching staff and should *not* be relegated to administrative paperwork. The process should not only be the result of cooperation among science teachers but should also serve to develop a feeling of collegiality among them.

The science department should have a systematic plan for evaluating individual courses and the science program as a whole. This does not mean that every course must receive a full scale examination every year but that the science department should have a planned cycle of critical review. Individual courses and the overall program should be reviewed intensively at least every four or five years. Leadership for this effort should come from the science chair.

Specific aspects to be considered include
- the relationship of program and course objectives to the current state of science, technology, and society.
- articulation between courses and with elementary and high school programs.
- how well the teaching methods fit the student learning styles.
- alternative and/or new courses that might better fulfill program objectives.
- objective evaluation of current courses in terms of student learning and interest.
- desirable modifications of current courses.
- equipment and facility needs.

Science Teachers

The single most critical learning resource in a good science program is the teaching staff. First rate buildings, rooms, equipment, or programs will not guarantee even a minimally acceptable science program without a good staff. Individually, science teachers need to be creative, enthusiastic, able to communicate, and knowledgeable about science, students, and teaching strategies. Science teachers should be selected carefully, supervised professionally, and assigned wisely. The following recommendations are intended to guide these actions.

34 Each science teacher should meet state certification requirements and be involved in frequent activities that will improve his or her science background and enthusiasm for the subject.

Subject matter background in science is important. However, enthusiasm about science and an active desire to continue to learn are more important.

34 The professional science teacher should
- **be well educated in science, liberal arts, and the philosophy and methods of teaching.**
- **continue to learn about science and science teaching throughout his or her teaching career.**
- **insist on a sound educational environment in which to work.**
- **contribute to the improvement of science teaching and the maintenance of high standards throughout the profession.**
- **take an interest in fostering a quality education for future science teachers.**

35 Science teachers should collaborate to maximize their combined backgrounds in science.

Teachers can learn from each other about science and science teaching, and they can occasionally trade classes for teaching certain units.

It is important that teachers view themselves as members of a team that is working to achieve common objectives.

35 The number of science teachers in a school should be large enough and their backgrounds in science broad enough to support a full science program.

Even the smallest school should have at least two science teachers. Not only will this enable the school to offer all science courses but will help assure professional growth of the teachers as result of their interaction.

Teachers should collaborate extensively and share their science backgrounds and teaching skills. Although it is unusual for a teacher to have an extensive background in all of the special sciences, teachers should have a broad background in science as a whole.

Science teachers should view themselves as members of a team dedicated to achieving many common objectives rather than as individuals teaching an isolated science.

Conditions of Instruction

Conditions of instruction refer to the circumstances in which each teacher works. The most important condition is probably the educational atmosphere. If there is trust and respect among students, teachers, and administrators; and if there is a team spirit that gives education of the individual student priority among school activities; it is likely that good conditions for learning and teaching will prevail.

The recommendations that follow deal with some of the specifiable aspects of conditions for instruction. They are based on the assumptions that a) a science teacher's total assignment must reflect the complexities of the job, b) there must be ample time for both instruction and preparation, and c) there should be provision for ample back-up support.

Teaching Assignments

To the science teacher there is nothing so discouraging and counter-productive as being so overloaded with school-assigned tasks that none of the tasks is done with a proficiency that reflects the teacher's abilities, skills and special knowledge. This is a problem in all teaching, but is a critical problem in science teaching in which amounts of equipment and material need to be managed. A related problem is the assignment of school tasks for which the teacher is not trained. The following recommendations are guides to minimize these problems.

36 Science instruction at the elementary level should be provided by teachers who are competent to teach science.

This recommendation is made to encourage the teaching of science at the elementary level, not to serve as an excuse to omit it. Ideally, science instruction at the elementary level should be the responsibility of a teacher or group of teachers whose primary function is to teach science. Whether science is taught by a science specialist or by the regular classroom teacher, the elementary science teacher must possess the science content knowledge, competence in methods, and personal interest to do an effective job.

36 A science teacher should fulfill all applicable certification requirements for each science course taught.

This recommendation should *not* preclude involvement in developing or teaching interdisciplinary courses, interdepartmental seminars, the use of team teaching, or other as yet unforseen innovations in instruction.

37 Specialized teachers of science in elementary schools should not meet more than three different grade levels or more than five separate classes each day.

Both specialized and "self-contained" teachers of science in elementary schools will be more effective if they can use adult aides and/or laboratory assistants selected from upper level students or pre-service teachers. This type of experience would be especially appropriate as an early field experience for prospective teachers.

37 A science teacher should have no more than three different course preparations.

Because of differences in the organization of science instruction, it may not be clear as to what constitutes a "course preparation." In a sense, every single class taught by a teacher constitutes a separate preparation. If a course is taught with individualized instruction, the teacher's preparation work increases by a factor of the number of students taught.

Whether a teacher primarily uses team teaching or

individualized instuction, there needs to be some reasonable limitation to his or her separate preparation situations.

School administrators need to recognize the extra time required by science teachers to manage laboratories.

38 Teachers who have the added responsibility of being lead science teacher or specialized science teacher should have fewer non-teaching assignments.

The extra demands of managing equipment and materials should be compensated by a reduction of non-teaching duties such as playground or lunch room assignments.

38 If science teachers are given responsible assignments beyond their usual classroom assignments, their total load should be adjusted to a reasonable level.

A teacher given an assignment such as department chairman, master teacher, supervisor of apprentice teachers, or chairman of a curriculum study group cannot be expected to carry it out effectively and still do full justice to the primary responsibility of teaching unless some adjustment is made. The adjustment should be in proportion to the magnitude and intensity of the added assignment.

39 Every science teacher's day should be arranged so that he or she has the equivalent of one period to meet with students on an individual basis, and/or to use as preparation time.

Because of differences in the organization of school day schedules, a period might be arbitrarily defined as containing 45 minutes. Students should know that consultation time with the science teacher exists and they should be free, within the rules of conduct of the school, to take advantage of it.

40 Science class sections should be strictly limited to 24 students per instructor or the capacity of the room, whichever is less.

Hands-on activities and laboratory experiments are an integral part of modern science instruction. Effective use of hands-on and laboratory based instruction requires individual participation by students and close student-teacher interaction. A 24 student restriction is necessary to maintain education quality. A teacher cannot supervise more than 24 students, even in the restricted sense of keeping order. The risk to student safety, and to expensive equipment escalates rapidly as the number of students in the laboratory at one time increases.

41 A specialized science teacher's involvement in extracurricular activities should emphasize the relevance of science to the whole school community.

A teacher of science provides the only real role model of "scientist" for most students. It is important to project an image that reflects the "normalcy" of scientists.

41 A science teacher's involvement in extra curricular activities should be limited to those with minimal stress and time requirements.

All teachers should share in the responsibility for carrying out the whole school program. Some extracurricular activities such as science clubs or science fairs can even be regarded as an extension of the formal job of science teaching.

Some extracurricular assignments, such as interscholastic sports coaching, have heavy time demands and generate stress levels beyond any dollar compensation. These may seriously detract from a teacher's ability to fulfill major teaching responsibilities.

On the other hand, some participation in extracurricular activities is necessary to keep the science teacher and science in tune with the total school community.

Working Space

Although space for instructional activities must be given priority, these facilities are not sufficient space for teachers. The nature of science and science teaching dictates that there should be places available where the science teacher can prepare for instructional activities.

42 Ample space is needed for the storage of supplies and equipment.

This space should be separate from and equivalent to at least 10 percent of the laboratory/classroom space it serves. It may be combined with storage space for materials for other subjects. Storage facilities should conform to accepted safety standards for the storage of materials and be under continuous adult supervision. Special arrangements must be provided for humane year-round care of animals.

This space should be separate from and equivalent to at least 15 percent of the laboratory space it services. Such space may be separate for each laboratory/classroom or be a common facility. Storage facilities should conform to accepted safety standards for the storage of materials and be under continuous adult supervision. Special arrangements must be provided for humane year-round care of animals.

This space should be separate from and equivalent to at least 15 percent of the laboratory space it services. Such space may be separate for each laboratory/classroom or be a common facility. Storage facilities should conform to accepted safety standards for the storage of materials and be under continuous adult supervision. If animals are kept permanently at the school, then a special animal room must be provided and arrangements made for year-round humane care of the animals.

43 Every science teacher should have access to a preparation area that is secure from student intervention.

This area need not be large or elaborate but should provide a place for teachers to set up and try demonstrations, arrange equipment, gather materials, etc. prior to their classroom use.

Teachers should have a place where they can prepare materials for student experimental work, set up and test demonstrations, and sometimes conduct experiments on their own. Depending upon the design of the separate science department, these teacher preparation areas should be separate from extended storage space. The preparation areas must be provided with convenient electric, water, and gas outlets, waste disposal facilities, and safety devices.

44 Every science teacher should have office space.

Teachers need a place where they can meet their students individually, where they can do their paper work without interruption, where they can keep files of confidential materials, and where they can organize a variety of teaching materials. If a teacher is the only one to use a classroom all day, it may be possible to use part of it as an office. Otherwise, private or semi-private office space should be provided. Ideally this space should

have a telephone or easy access to one. A semi-private office has the advantage of increasing professional interaction among science teaching colleagues.

45 The science teacher needs access to a professional library.

Science teachers, faced with the task of staying up-to-date in science, science applications, science teaching, and the relationships of science to society, carry a considerable academic burden. Consequently, teachers frequently need to study appropriate books and journals and cannot function effectively for long without these resources. Teachers should have immediate access to a professional library that contains appropriate material. This library should exist as a separate facility within the school or could be a part of a group office.

The opportunity to further one's knowledge base by having a readily accessible professional library is one of the personal rewards of teaching science.

Services

A science teacher needs assistance to do the job of teaching well. A talented instructor is not always a talented clerical worker or equipment cleaner and repairer, and certainly instruction has priority.

It is not only with "chores" that a science teacher needs help, however. Teachers can do a better job of teaching if they have frequent contact with new ideas and methods which extend their experience and knowledge.

46 Schools should appoint one teacher as lead science teacher or science chairperson.

The main function of this chairperson is the improvement of science teaching and learning. This person provides leadership in staff development, curriculum development, materials, management, and coordination of teachers' efforts toward achieving school goals. The chairperson should have an excellent professional background, high standards, and be a dedicated teacher.

46 Schools employing three or more science teachers should have a science department headed by a chairperson.

The main function of the chairperson is the improvement of science teaching and learning. This person provides leadership in staff development, curriculum development, materials management, and coordination of teachers' efforts toward achieving school goals. The chairperson should have an excellent professional background, high standards, and be a dedicated teacher. This person's teaching load should be adjusted to give him or her at least one hour each school day for fulfilling departmental responsibilities.

47 Professional laboratory assistants should be available.

The chief tasks of these assistants would be maintenance of materials, supplies, equipment kits, aquariums, etc., and assistance on field trips and other non-classroom learning activities. In some situations, qualified volunteers may do the job. In larger schools or systems a full-time paid professional may serve several schools.

Teachers in training from local colleges could gain early field experience by serving in this position.

The chief tasks of these paid adult assistants, or qualified and/or advanced student assistants, would be to assist the teacher with such things as setting up demonstrations and student laboratory experiments, and ordering, assembling, maintain-

ing, and keeping an inventory of supplies and equipment. Advanced students could receive special course credit in lieu of pay.

Teachers in training from local colleges could gain early field experience by serving in this position.

48 Regular professional secretarial and clerical help should be available to science teachers.

This help should be available at least two hours per week at a time convenient to the teacher.

This help should be available at least one hour a day to each teacher at a time convenient to the teacher. Student help is ordinarily an unsatisfactory substitute for this.

49 Consultants and specialists should be called in to help teachers of science as needed.

These may be specialists on new science programs, specialists in using new learning technology, science educators to help individual teachers with classroom problems, safety engineers, and the like. Contact with one or more of these outside persons should occur at least once each school year.

An organized science volunteer group may be able to provide talks, tours, etc. to update teacher knowledge and even help in locating used but useful materials and equipment locally.

49 Consultants and specialists should be called in to help the science department and science teachers as needed.

These may be specialists in new science programs, specialists in using new learning technology, science educators to help individual teachers with classroom problems, safety engineers, and the like.

Proper use of consultants will result in a dynamic group of teachers that continue to develop their knowledge, skills, and interests.

50 Each school system should have a voluntary Science Advisory Group drawn from the community. Its focus should cover grades K-12.

This group will provide a two-way commmunication line between community and teachers to share needs and concerns. This group would be strictly advisory and would not have policy making power. Its composition should vary gradually from year to year.

Budget

Each science teacher must be supported by an adequate budget. Because of local differences, it is not practical to specify exact budget amounts in this document. It is imperative, however, that the budget include both operating and equipment acquisition costs and that science teachers are directly involved in establishing the budget. The following recommendations provide some guidelines for the development of an adequate budget.

51 The science budget should appear as a separate account within the whole school budget, and it should be subdivided according to function.

Separate line items should indicate the amounts budgeted for the purchase of laboratory equipment, for the repair and maintenance of equipment, and for supplies. This will eliminate unnecessary confusion over the true size of the science budget, or over the relative distribu-

tion within the department of capital expenses and annual operating expenses. Such information is necessary if science teachers are to plan their work efficiently.

52 Supplies (expendables) should be budgeted on a per learner basis with the amount varying according to the nature of the course, the grade level of instruction, and the expendables involved.

It must be kept in mind that there is a basic budget below which any science class or course cannot operate, no matter how few students are enrolled.

53 Budget provisions need to be made so that certain items may be purchased as needed during the school year. These items will often be locally obtainable. They include perishable materials and items for which need develops as a result of unforseen class interest and development.

A substantial petty cash fund should be established to meet this need. It should be accessible to all teachers involved in science with approval by the science chairperson or lead science teacher.

A substantial petty cash fund should be established to meet this need. It should be accessible to every teacher in the science department with approval by the chairperson. This fund could be supplemented by laboratory fees if these are permitted.

54 Simple but useful laboratory materials should be obtained from local business and industry surplus to supplement regular budgetary sources. Such material might include obsolete wire, glassware, and storage boxes.

Local service and educational organizations can be enlisted in the search for usable material. In a real sense, the community thus supports schools with resources other than actual dollars.

54 Major equipment acquisitions should be planned on a 3-5 year basis with priorities set by a consensus of the science teachers.

It is recognized that budget restrictions may prevent needed funds from coming from the school budget. Teachers and administrators should take the initiative in identifying and applying for foundation grants. This will be especially effective if done on a dollar matching basis. Local service organizations, businesses, and industries may also be able to provide resources if a need is clearly documented.

Professional Growth

Science teaching is such a complex, dynamic profession that it is difficult for a teacher to stay up-to-date. For a teacher to grow professionally and become better at the teaching of science, a special continuous effort is required. During the first few years of science teaching, each teacher needs special help and consideration. Then, throughout the teacher's career, opportunities should be provided to enable teachers to extend their skills and knowledge. There also needs to be special provision to help teachers recognize their value and status in the community. These opportunities are necessary if intellectual and professional stagnation are to be avoided. To assist science teachers with a continuous program of professional growth, the school or district should provide a well stocked professional library, support a variety of learning opportunities, and establish incentives to encourage self-improvement.

Professional Library

Science teachers need access to a professional library to do their day-to-day work. Beyond that, they need this resource to develop understanding and skills that are part of the profession. Teachers need to keep current in science, science teaching, and societal effects of science and technology. While the school's professional library will contain books, journals, and other material of general educational interest, it should have items of special interest to teachers of science. The following recommendations deal with the latter area.

55 The school's professional library should contain a selection of books on both science teaching and science. Books containing collections of science activities for elementary children should be emphasized.

The activity books should be useful in enriching the teacher's background in science and relevant to the program being taught in the school. Books should be those recommended by the school's teachers and professional science teacher organizations.

55 The school's professional library should contain a large selection of books on science education, science, and the history and philosophy of science and technology. Books should be those recommended by the school's science teachers and professional science teacher organizations.

56 A collection of science education journals should be maintained in the school's professional library. These might include: *Science and Children* and *School Science and Mathematics*.

Most journals publish material for and by experienced science educators. Articles from practicing classroom teachers are especially important. Teachers are encouraged to submit manuscripts for possible publication.

56 A collection of several professional education journals should be maintained in the school's library. These might include: *The Science Teacher, Science and Children, The American Biology Teacher, School Science and Mathematics, The Physics Teacher*, and *The Journal of Chemical Education*.

Most journals publish material for and by experienced science educators. Articles from practicing classroom teachers are especially important. Teachers are encouraged to submit manuscripts for possible publication.

57 An up-to-date and relevant file of science curriculum materials and information should be maintained. These materials should include curriculum guides, unit plans, catalogs of equipment and materials, catalogs of educational computer programs, sample teaching modules from a variety of projects, rele-

vant research reports, announcements of relevant graduate courses, etc.

Sources for these items should include local and state education agencies, local universities, funded curriculum development projects, the Educational Resources Information Center (ERIC), curriculum development projects, Department of Education Regional Offices, the National Science Teachers Association, and other professional groups.

58 The professional library, at either the school or district level, should contain one or more microfilm/microfiche readers and draw heavily on the output of the Educational Resources Information Center (ERIC). The ERIC Clearinghouse for Science and Mathematics is located at Ohio State University in Columbus. As schools add computers for educational use, software for science and science data banks should be available.

Most of the important educational journals are now in microforms, making it relatively inexpensive for a school to have a substantial holding of back issues of science education journals even if subscriptions to these journals have recently been established. In addition, hundreds of valuable reports and documents are available on microfiche from ERIC at low cost. Along with a growing file of ERIC microfiche, the library should subscribe to the two main ERIC guides, *Research In Education* and *Current Index to Journals in Education*, both of which are useful to practicing teachers as well as to educational researchers and reference librarians. *The Thesaurus of ERIC Descriptors* should also be on hand.

Continuous Learning

A science teacher cannot grow professionally by merely reading. Books, journals, and innovative curriculum materials can extend one's knowledge of some aspects of science, education, and current trends. However, to fulfill one's human potential it is necessary to interact with other people and their ideas and to get involved in projects. This implies contact with people in schools, universities, and science and technology related professions beyond those in the immediate school.

School policy should encourage science teachers to identify these resources and opportunities. Incentives and recognition of achievement can provide the basis for this encouragement. The recommendations that follow indicate some ways of doing this.

59 Schools should provide opportunities for the inservice education of science teachers throughout their teaching careers.

Teachers should have a voice in determining the content and structure of the in-service program. Released time should be available for the program, and the cost should be underwritten by the school as part of its regular operating budget. In return, the school should require teachers to regularly participate in the in-service program or in some equivalent self-improvement activity, such as summer school or special workshops.

60 Paid sabbatical leaves should be provided for the periodic updating and further educational development of science teachers.

After seven years of teaching, teachers should be entitled to a minimum of a half-year leave at full pay or a full year leave at half pay. This pay should not be reduced for teachers who obtain a grant or other source of support during the period of their leave.

61 After seven years, a permanent teacher should be permitted to take a leave-of-absence of up to two years for purposes of further education without jeopardy

to his or her current position or salary advances upon return to the system.

62 Elementary teachers should be encouraged to spend time with other teachers who have demonstrated expertise in science teaching.

Science may be the most rapidly changing area of the many which the elementary teacher is asked to teach. Good science teaching at the elementary level makes use of a wide variety of classroom management skills. For these reasons, elementary teachers need to spend time visiting with master teachers and specialists in the area of science.

62 Adminstrators should realize that the nature of science demands that science teachers have time each year to be away from school for professional purposes.

These days should be equitably distributed among the science teachers in the department and should average at least one day per teacher per year. They should be used for visits to other schools, to colleges and universities, to research centers, to industry, etc. These visits will help the teacher keep abreast of current development in science and science teaching. Reciprocal visits with science teachers from other schools should be encouraged.

63 Support should be given so that all science teachers can attend and participate in local, state, and national science teacher conventions.

Time and at least some reimbursement for travel, room and board, registration fees, and some expenses should be provided to teachers on a rotating basis. The school should make it possible for every science teacher to attend a national convention at least once every four years, and state and local ones more often. Special consideration, in terms of reasonable time off from school without loss of salary, should be given to teachers who hold a major office in a state or national science teachers professional association.

Teachers should also be willing to support their own professional growth by contributing some of their own time and money.

64 Elementary teachers should be urged to attend special teacher institutes dealing with new science curricula and new scientific developments.

Although federal funding for this sort of workshop has all but disappeared, other sources of funding are beginning to surface. NSTA, local, and state science education groups are actively pursuing these sponsors. Elementary teachers should be encouraged to attend workshops which have been endorsed by the NSTA, their state elementary teachers association, local universities, and/or teacher centers. These workshops are well worth the time and effort involved. Many of them are developed specifically for special groups of elementary teachers.

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time and effort involved. Many of them are developed specifically for special groups of science teachers.

65 First and second year teachers, and teachers who have changed grade level, should be given extra assistance in their teaching of science.

Special "buddy" teachers who have demonstrated expertise in science teaching should assist these teachers in learning about the topics, experiments, materials, discussions, and classroom management skills necessary to develop a successful science program. In larger districts, science specialists should be available to work with these teachers in their classrooms.

65 First and second year teachers should be given special assistance and consideration.

The first year or two of teaching are likely to be intellectually and emotionally taxing, but they are especially important years. These are often the years during which a new teacher's attitudes are set, basic teaching skills are learned, and the course for the future is fixed. It is crucial, therefore, that the school have a special concern for the new teacher's training and self-improvement. There are several concrete actions that can be taken. One is to set the beginning teacher's instructional and extracurricular load well below that of experienced teachers in the department. At least during the first year as a science teacher, he or she should have only one academic preparation, and his or her number of student contacts should be limited to approximately three-fourths of that of experienced teachers. Second, professional help should be readily available to assist the beginning teacher with classroom problems. The science department head can function in this capacity, as can the master teachers in the science department. Third, the department head and other experienced science teachers in the department should introduce new teachers to professional association activities and take them to professional meetings of special interest.

Recognition and Incentive

To expect a science teacher to devote time and energy to self-improvement on top of regular teaching responsibilities makes sense professionally, but it may not always be realistic. Many teachers are unlikely to undertake or continue the rigors of such improvement unless they have a strong incentive to do so. Theoretically, the strongest incentive should be the knowledge that further training and study will lead to improved teaching. Still, teachers, like other people, eventually beome discouraged if extra work seems to bring no reward or acknowledgement. It is important for the school not only to support a strong professional growth program in the ways indicated above but also to provide special incentives and recognition to teachers who do take advantage of opportunities to improve throughout their careers.

66 Teachers who have pursued a program of professional improvement and reached a superior standard of teaching competence should be rewarded with special recognition.

This might take many forms, but at least it should include increased salary, special status as a master teacher, assignment to training and supervision responsibilities, and perhaps a citation as an outstanding professional science educator.

67 Teachers who have attained a special status through advanced study, etc. should occasionally be given the opportunity to work on projects of their own choosing.

These projects might include such things as developing new instructional materials, conducting research on science or science learning, or developing a new interdisciplinary course with other teachers in the school. Operationally, this opportunity should take the form of adjusting the teacher's instructional load and of providing some financial support if needed.

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